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PERFORMANCE TESTING OF FIBERBOARD SHIPPING CONTAINERS

by
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Approved for Public Release; Distribution is Unlimited

**U.S. Army Soldier and Biological Chemical Command
Soldier Systems Center
Natick, Massachusetts 01760-5018**

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14. ABSTRACT Solid and corrugated fiberboard is available in a range of grades and finishes. This investigation centered on the potential use of less expensive, more available, and more environmental-friendly fiberboard in the construction of boxes used for the packing of Military rations. Meal, Ready to Eat (MRE) rations were used for this investigation. Boxes were constructed from different fiberboards and then packed with rations. These boxes were then subjected to testing in accordance with ASTM 4169-96: Standard Practice for Performance Testing of Shipping Containers and Systems. Distribution Cycle 18 (Government Shipments) and Assurance Level I (highest intensity/most severe) were selected as test parameters. Evaluation of the test results leads to the recommendation that the use of solid fiberboard be discontinued as corrugated fiberboard has been proven acceptable for the packing of all MREs. It is also recommended that a regular slotted container (RSC) box design with inner fiberboard inserts be adopted for packing of MREs. A redesign of the MRE box to accommodate more meals, achieving an optimum container weight with resultant cost savings, should also be considered.					
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PREFACE

This research was conducted during under the Savings Through Value Enhancement (SAVE) Project: *Modify MRE Shipping Container Using V3c Fiberboard* and the Military Service Requirement (MSR) Program: *Multi-Service Ration Packaging and Packing Recycling Initiative*. The research was conducted during the period of January 1998 through September 1998 at the U.S. Army Soldier Systems Center under U.S. Army contract no. 814AAN3123.

Project Officer for these programs is Mr. Maxwell Meyers, Food Engineering Services Team, DoD Combat Feeding Program.

Technical support provided by Mr. Jack Barber of the Group Ration Team, DoD Combat Feeding Program, was vital to this project.

PERFORMANCE TESTING OF FIBERBOARD SHIPPING CONTAINERS

I. Introduction.

a. Objective. One of the goals of this effort was to identify an alternate fiberboard to replace the V2s grade fiberboard currently used in the packing of the Meal, Ready-to-Eat (MRE) ration.

Another goal was to attain source reduction of packaging materials while maintaining the durability of the shipping containers during military distribution.

b. Background. The current fiberboard used in the packing of MREs is a V2s grade solid fiberboard, with a thickness of 0.090 inch, a dry burst of 550 lb and a wet burst of 500 lb. The bursting strength (measured in accordance with TAPPI T810: *Bursting Strength of Corrugated and Solid Fiberboard*) is an indication of the character of the fiberboard. This test procedure is also sometimes known as the burst test. Another essential parameter of a fiberboard is basis weight (BW), measured as pounds per 1,000 square feet of paper, of the individual linerboard sheets of fiberboard. V2s grade fiberboard is constructed of 2 inner sheets of 69 lb and 2 outer sheets of 90 lb linerboard joined with wet strength adhesive. Though this fiberboard performs admirably it is costly, heavy, not readily available in the marketplace, and has very low repulpability thereby making it an undesirable material for recycling.

The other common fiberboard used for military ration packaging is a V3c grade corrugated fiberboard, with a dry burst of 400 lb, a wet burst of 150 lb, and a thickness of approximately 0.18 inch. The construction is 2 outer sheets of 90 lb linerboard and an inner corrugated ply of 33 lb C flute corrugated medium. The flutes, which come in a range of sizes, in the corrugated medium provide resistance to bending and pressure from all directions and provide great stacking strength. V3c fiberboard is an expensive specialty fiberboard that has better repulpability than V2s, but is still not a preferred material for recycling.

V3c and V2s and other 'V' fiberboards are classified in American Society of Testing and Materials (ASTM) D 4727: *Standard Specification for Corrugated and Solid Fiberboard Sheet Stock (Container Grade) and Cut Shapes*. They are weather-resistant fiberboards that are constructed with special adhesives and resins and are designed to meet a wet burst requirement. The 'c' and 's' in the designation defines 'corrugated' or 'solid' fiberboard. Domestic fiberboard, designated by its minimum dry burst requirements, are commercial materials.

The current MRE container is a regular slotted container (RSC) box design (glued joint and flaps) constructed from V2s fiberboard. It is fitted with a V2s sleeve (glued joint) banded by 2 nonmetallic straps. A filled box contains 12 rations, weighs about 23 pounds, has inside dimensions of 16-1/4 x 9-1/8 x 9-7/8 inches, and has a cube (the volume of space occupied by the unit) of 0.95 cubic feet.

The Unitized Group Ration (UGR) container was also evaluated. It is a V3c box with glued joint and flaps and is fitted with two V3c liners that divide the container into two equal compartments. The inside dimensions are 23-3/4 x 13 x 8-3/4 inches. A filled box weighs between 35 and 45 pounds and has a cube of 1.6 cubic feet.

Boxes submitted by the industry were also tested. MRE and UGR boxes were sometimes modified to emphasize particular materials or designs. More detailed descriptions of the boxes tested are found in Appendix D: Test Results.

II. Test Method

After consideration of the available methods to evaluate fiberboard box designs, it was determined that the American Society of Testing and Materials (ASTM) D 4169 - 96: *Standard Practice for Performance Testing of Shipping Containers and Systems* would be used. Distribution Cycle 18 (Government shipments) and an Assurance Level of I (highest intensity/most severe) were selected. Appendix C describes this testing cycle, with notes of any parameters/deviations utilized in this evaluation.

A survey of the fiberboard industry was conducted (Appendix A). Various fiberboards were obtained and evaluated (Appendix B).

Many box designs, with several different assembly/closure/sealing/reinforcing techniques, were evaluated. A range of box sizes were tested. All containers were essentially an RSC box design, modified with fiberboard lines or sleeves.

After all observations and measurements were obtained, a subjective Pass / Fail determination was made. A box passed if it retained all contents, had good compressive strength, had no major gaps or tears (holes less than 1-inch in any dimensions considered acceptable), and could still be manually handled. Conversely, a box was deemed a failure if it had major holes or gaps, poor compressive strength, contents spilling out or exposed, or could no longer be manually handled.

III. Results and Discussion

When comparing various fiberboards, solid fiberboard (especially V2s) is expensive, is produced by few manufacturers, does not repulp easily, and is not recyclable. Solid fiberboard is heavier than corrugated board and is harder to fabricate, requiring special scoring equipment.

Corrugated fiberboard provides great stacking strength for its weight, is readily available, and is recyclable. V3c fiberboard, when treated with water-resistant resin, re-pulps at a lower than desired rate, but does not need to be excluded from the recyclable collection stream.

The need for weather-resistant fiberboard is debatable. When comparing a box constructed from weather-resistant fiberboard to a non-treated domestic fiberboard, the weather-resistant box exhibits a slightly higher retention of box squareness and integrity, but the differences in cost, availability and recyclability must also be considered.

When evaluating the performance of boxes subjected to ASTM D 4169 testing and the discussion on compression strength requirements (see addendum), it is recommended that boxes be designed to a minimum safety factor of 5, with a safety factor of 6 desired. Use of grade 275 fiberboard to construct a box with an inner partition resulted in a container with insufficient compressive strength. An RSC box constructed from a 350 grade (or an equivalent ECT (Edge Crush) grade) fiberboard and fitted with inner liners constructed from grade 275 board demonstrated acceptable compressive strength.

The adoption of an alternate container, a box with dimensions large enough to contain eighteen MRE rations, would result in less cost (one third less boxes translates to major savings), less weight, less waste, reduced labor (in the manufacture, set-up, closure and handling of boxes), and reduced shipping costs. An 18-pack container would allow the same number of meals per unit load with less pallet overhang. The adoption by the military of an 18-pack box would lead to an increased cost for a case of MREs but a significant overall cost savings, an increased weight of the case (from 23 lb to about 32 lb, which is still below the recommended weights for a one-person lift), the re-education of the users, and the update of logistics data.

The current MRE container design with an RSC box and an outer sleeve is expensive, bulky, requires strapping, and generates excessive waste. An RSC box with inner fiberboard supports is recommended.

IV. Conclusions

The use of solid fiberboard for military ration packing should be discontinued.

A V3c grade fiberboard RSC box with inside dimensions (ID) of approximately 16-1/2 x 9-1/4 x 9-7/8 inches, with a full height inner liner is recommended. The manufacturer's joint shall be glued, and the box shall be set-up and closed/sealed in accordance with Method B or C of ASTM D 1974, with tape conforming to Type I or V of ASTM D 5486.

If a decision is made to adopt the 18-pack, the same V3c grade fiberboard RSC box design in the proper dimensions is recommended.

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APPENDICES

APPENDIX A

FIBERBOARD COMPANIES CONSULTED

Chesapeake Packaging Co. Sandston, VA 804-328-4132 Barney Flaherty

They produce linerboard. When producing solid fiberboard, a 100% coverage of adhesive is required, increasing weight, cost and "stickies" (non-paper materials that foul up the repulping equipment). With corrugated fiberboard, the adhesive is only applied at the flute tips. The 'most friendly' (environmental friendly and manufacturing friendly) adhesive is starch-based. In water-resistant adhesives, resins are linked to the starch.

Coatings are usually emulsions with acrylics and some wax.

Solid fiberboard, such as V2s, is normally constructed from 3 or 4 sheets of 90 lb basis weight (BW) linerboard, with a finished BW of about 337. Suggested an E-flute adhered to 90 lb linerboard, which would have a finished BW of 230, leading to about a 30% cost savings, and which may allow use of a different adhesive.

Consolidated Papers, Inc. Wisconsin Rapids, WI 715-422-3660 Christine Del Hoyo

Produces a domestic 0.09 inch weatherproof fiberboard which is non-bending and cannot be used for box making.

Gaylord Container Corp. Bogalusa, LA 504-732-8813 Bill Wellons

Conducts research into alternate wet-strength adhesives for use in the construction of corrugated and solid fiberboard. They have found no fiberboard construction using the newly-developed adhesives that will achieve the wet burst requirement (500 lb) required for V2s grade fiberboard, but have made board with about a 400 lb wet burst. Wet strength adhesives do not provide moisture resistance but do prevent the board from delaminating.

Wet strength paper, such as that used in producing V2s fiberboard, is not recyclable. The local paper mill will not accept their wet strength paper trimmings (called "broke").

Recently upgraded their solid fiberboard line.

Have not experimented with coatings that would reduce moisture penetration. Their recently developed coatings are not printable or gluable. New coatings are water-based.

Produces a stitched 3-piece Bliss box for returnable beer bottles. The fiberboard is constructed from three 69 lb liners and one 42 lb liner (finished BW of 249 lb) and is coated to resist moisture and dirt. These boxes make 12 - 15 trips, with most boxes rejected from continued use because of cleanliness, not because of a loss in box integrity.

Linerboards used to construct V2s, V3c and W5c fiberboards are treated with a resin in a procedure called sizing. Sizing increases wet strength, and decreases recyclability. Only two US mills produce sized linerboards, which affects cost and availability. The 69 lb and 90 lb linerboards contain up to 19% recycled content while thinner linerboards contain up to 45% recycled content.

V2s is 0.09 inch thick and constructed from two 90 lb linerboards and two 69 lb linerboards. Wet burst requirement is 500 lb. Finished BW is 318 lb. The linerboards used for V2s fiberboard are sized and therefore are not recyclable.

V3s is 0.09 inch thick and constructed from two 90 lb and two 69 lb linerboards, with a wet burst requirement of 150 lb. Finished BW is 318 lb. It is recyclable. The V3c fiberboard evaluated for this project averaged 200+ lb wet strength and 800+ lb dry burst.

V4s is 0.08 inch thick and constructed from four 69 lb linerboards with wet burst requirement of 150 lb and finished BW of 276 lb. It is recyclable and bends easily to form boxes.

Estimated cost savings if the military adopted a V3s non-sized board instead of the V2s wet strength board is \$20 per ton, with an annual savings of approximately \$100,000. (Note: 1997 quantity of fiberboard used for MRE packing was about 4,000 tons.)

Georgia-Pacific

Norcross, GA

770-246-1402

Jim Perry

A formaldehyde resin is added to the paper to create wet strength. Weather-resistant starch adhesives resist water penetration. Coatings shed water, but are not good for vapor resistance. Wax-coated boxes are not recycled, but may be reclaimed by burning for energy.

Georgia-Pacific (G-P) conducts ASTM D 4169 testing. They also use Lansmont brand damage detectors.

G-P tested the repulpability of V3c and V2s fiberboards using a disintegrator. Normally, a slurry is produced after 250 counts. V2s board, after 7000 counts, still had lumps. The V3c board, after 4000 counts, was almost completely pulped.

Natick sent an MRE box to G-P for review.

G-P sent a drawing of an auto-divide RSC box plus two sample boxes for testing.

International Paper Co.

Shreveport, LA
Putnam, CT

318-929-4112
800-826-0592

Bob Bartles
Doug Ewing

Mr. Bartles works with the "Fibreshield" coating line. Fibreshield is a recyclable/repulpable coating (FDA approved for direct food contact) which can replace wax-coated boxes in some scenarios. This coating slows moisture penetration. Coatings may be more effective with solid fiberboard than in corrugated fiberboard, since in corrugated board there is a wicking penetration of water up the flutes.

Mr. Ewing stated that they produce corrugated fiberboards with the following flute sizes: B, C and double wall B/B. They do not use 90 lb linerboard, but use some 75 lb linerboard. 42 lb linerboard is their most common material.

Longview Fibre Co.

Rockford, IL

815-877-8011

Ron Phillips

Produces corrugated boards using all flute sizes, including maxi-A (.25 inch), L (.375 inch) and E (small). Recommends consideration of an E-flute corrugated fiberboard. E-flute is a small flute (90-98 flutes/foot).

They agreed that corrugated fiberboard, even with weather-resistant materials, tend to come apart. Wax treatments are expensive. They would consider applying Stone brand coatings.

They produce wet strength fiberboards. They also have some government contracts.

Lydall Southern Products

Richmond, VA

716-544-9150

Charles Palmer

804-266-9611

Phil Mullins

Producers of solid fiberboard. Can produce V-grade weather-resistant fiberboards.

They use a polyvinyl alcohol adhesive that is moisture-resistant, recyclable and inexpensive. This adhesive is safer than formaldehyde-based adhesives and has increased moisture protection when compared to starch-based adhesives.

Michelman brand coatings create no recycling problems and do not deteriorate over time. Recyclers will pay \$50 – 60 per ton for solid fiberboard.

Natick provided them with an MRE box sample.

Natick received from Lydall 15 sheets (40 x 60 inch) of 0.085 and 5 sheets of the 0.085 in. board with both sides coated. These boards have a BW of 345 lb and are constructed from 6 sheets of linerboard. Dry burst strength is greater than 550 lb. Cost was quoted at \$2.33 / sheet. This fiberboard was made into sleeves and subjected to the ASTM D 4169 test cycle. The fiberboard passed.

Massachusetts Container Corp

Marlboro, MA

08-481-1100

Terry Moore

They are developing corrugated fiberboards that might replace V3c.

Their facility has established a Michelman brand coating line.

Mass. Container Corp. representatives visited Natick, observed boxes that had been subjected to the ASTM D 4169 test and discussed possible approaches.

They determined that a 44 ECT (edge crush test) fiberboard is equivalent to 275 lb board at about a 4% cost savings.

<u>MacMillan Bloedel Packaging Inc.</u>	Henderson, KY	502-831-6000	Larry Griffin
	Pine Hill, AL	800-637-6449	Owen Goff

The Henderson mill makes linerboard in the 17 – 38 lb BW range, using 100% recycled content from old corrugated containers (OCC). The Pine Hill mill makes heavier linerboard and fluted medium.

They noted that repulpable resins to replace urea formaldehyde resins are becoming more available. They mentioned Georgia-Pacific as a source for these new products.

<u>Menasha</u>	Menasha, WI	920-751-2337	Dan Oberbrunner
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They produce domestic solid fiberboard, as well as kraft or chipboard linerboards. They also produce coated fiberboards. Their fiberboard has a thickness range of 0.022 - 0.200 inch. They use mostly 69 lb and 90 lb BW linerboards.

They suggest a 62 lb wet strength linerboard to provide increased tensile strength.

Natick sent them an MRE box sample.

A sample of solid fiberboard was sent to Natick, constructed into an MRE sleeve and tested. This fiberboard performed well. It has a thickness of 0.072, finished BW of 310 lb, and a dry burst strength of about 700 lb. Menasha claims that the board is recyclable.

<u>Niagara</u>	Lockport, NY	716-434-8881	Dick Cain
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Niagara produces domestic solid fiberboard. They claim their products are 100% recyclable.

Recommend sizing the fiberboard to increase weather-resistance (to provide better “hold out”).

Natick faxed them a letter explaining the MRE material and box design.

Niagara claims that their best off-the-shelf solid fiberboard has a dry burst of approximately 400 lb and wet burst of less than 200 lb. However, samples received were a chipboard type of board, which is unacceptable for MRE packing.

Stone Container

Mansfield, MA 508-339-3601
Westmont, IL 60559-5526 630-920-9600

Charles Bonadio
Tom Appelhans

Stone has a coating called "BlocKit" that offers protection from water, moisture and grease damage, and is recyclable.

They are a manufacturer of corrugated fiberboard and can produce all flute sizes (super A, A, B, C, E, F). They use a pearl starch adhesive. Use of additives can increase the water resistance of the adhesive.

Recommended that a full overlap slotted container (FOL) box be considered. This design, produced by a die-cut operation, would have flaps that meet, thus providing increased stacking strength due to two thicknesses of board.

They visited Natick. They delivered a sample of a fiberboard constructed from 69 lb linerboards with C-flute medium, coated both sides. Natick provided Stone with an MRE case.

A repulp test of V2s and V3c fiberboard was conducted by Stone. V2s was 25% repulpable, V3c was 80% repulpable.

Victory Container Corp.

Roselle, NJ 908-245-5100

Ruby Baum

A corrugated fiberboard converter. They buy linerboard (sized and unsized) from other mills. Not producing V3c board anymore.

Weyerhaeuser

Tampa, FL 813-908-5117

Marcia Smith

Natick sent Weyerhaeuser V2s and V3c fiberboard samples for repulpability testing. Results showed a repulpability of about 55%; the industry goal is about 80%. V3c was better than V2s, but both are well below the acceptable range.

Solid fiberboard and the use of 90 lb linerboards are both becoming less available in the industry. Weyerhaeuser produces 47 lb and 62 lb linerboards.

Forest Products Lab

WI

608-231-9425

608-231-9437

Gary Meyers

John Klungness

Forest Products Lab (FPL) provided Natick with an overview of their programs.

Alkaline sizing allows more filler to be used in paper. Calcium carbonate enhances sizing. The use of fillers and waterproofing materials reduces capillary action (edge wicking of moisture or grease). Improved sizing will maintain or increase the strength of the linerboard.

They soaked a V3c fiberboard sample for 20 minutes and determined it "wasn't very water resistant". They emphasized that for corrugated fiberboards, the proper adhesive is vital.

Solid fiberboard, due to its construction, is resistant the wicking water of water into the board. With a sizing resin, you will achieve high wet tensile strength. And a coating will protect the fiberboard in the short term.

Dual use of boxes (i.e., filling with sand and constructing bunkers) is an area worth pursuing, lengthening the service life of the box.

They advised that it might be easier to recycle solid fiberboard into a "hardwood" panel product. The 'stickies' (clumps of adhesives, glues, resins, and non-paper components) are retained in this process.

They emphasized transportation costs as a major factor when calculating life cycle costs.

Combustion requires a large facility that meets EPA standards. And there is a concern for air pollution and ash disposal. Composting may create methane, which contributes to global warming.

FPL participates in cooperative research and would consider a joint venture with Natick.

Fibre Box Association

Rolling Meadows, IL

847-364-9638 Mary Alice Opfer

They recommended domestic fiberboards with regular linerboards, plus water-resistant adhesives. Polyvinyl alcohol adhesive is water soluble and expensive.

Coatings on fiberboard tend to make the board unrecyclable. Coatings can shed incidental water. Michelman brand coatings are recyclable; but they are water resistant, not waterproof.

Coatings keep the fiberboard from getting wet; adhesive keeps fibers together.

They suggested evaluating a corrugated fiberboard with a dry burst strength that is equivalent to V2s; this corrugated board would have increased top-bottom compression strength and decreased wet strength.

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APPENDIX B

FIBERBOARD CHARACTERISTICS

Material	Manufacturer	Thickness, inch	Basis Weight, lb/1000ft ³	Dry Burst, lb <u>1/</u>	Wet Burst, lb <u>1/</u>
Solid Fiberboard					
V2s	Gaylord	.079	326	800	590
Lydall <u>2/</u>	Lydall	.082	337	840	435
Lydall Coated <u>2/</u>	Lydall	.084	340	850	530
Menasha	Menasha	.072	310	760	555
Corrugated Fiberboard					
V3c	Unicorr	.179	227	540	215
275	Unknown	.174	175	440	70
Fibreshield <u>3/</u>	International Paper	.120	160	440	50
GP USP 120/33C+WR A/USP120	Georgia- Pacific	.175	170	480	Not tested

1/ Sampling was based on availability of material and these averages reflect this variability. In general, dry burst is an average of 5 samples, and wet burst is an average of 3 samples.

2/ 6-ply virgin kraft, polyvinyl adhesive Michelman© coating both sides.

3/ Coating on inside.

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APPENDIX C

TEST METHOD

This Test Method is derived from ASTM D 4169 - 96: Performance Testing of Shipping Containers and Systems

Distribution Cycle: 18 (Government shipments)

Assurance Level: I (High test intensity)

Except during the water spray periods, boxes were set on a sheet of V3c corrugated fiberboard on a flat bed truck.

Boxes were stored and tested at ambient temperature (65 - 75°F) when not being exposed to the environmental test cycle.

1. Handling **Drop Test** ASTM D 5276 - 94

21 inch height

- 1 top
- 2 adjacent bottom edges
- 2 diagonally opposite bottom corners (not on joint)
- 1 bottom

Note: Some box designs required that the RSC box to be turned 90° and then the sleeve be placed around the box; the manufacturer's joint is then one of the bottom edges of the box.

2. Stacking **Compressive Resistance** ASTM D 642 - 94

Set compressive weight at target weight, which is cited in Appendix D for the specific boxes tested. If a steady state (with little or no change in load) is reached before this levels, discontinue test and record the load (lb) and the displacement (inches).

3. Handling **Drop Test** ASTM D 5276 - 94

21 inch height

- 1 vertical edge
- 2 adjacent side faces
- 2 one top corner (not on joint) and one adjacent top edge
- 1 bottom

4. Environmental

<u>Conditions</u>	<u>Hours</u>	
120°F	16	
Water Spray	2	
-10°F	2	
120°F	2	Water spray was waived. See note.
Water Spray	2	
40°F	16	
120°F	4	A minimum 3-inch clearance
Water Spray	2	on all sides of the boxes was maintained.
40°F	2	
120°F	16	Water spray 4 inches/hour \pm 1 in.
Water Spray	2	Two nozzles propel the water down in a
-10°F	2	small radius; the positions of the boxes
40°F	3	were varied each time to give a more equal
120°F	16	exposure.

Note: ASTM D 4169 cites a 2-hour water spray at 120°F. This facility does not have the apparatus to perform this test. Using rationale that the boxes being tested are normally stored and transported in unit loads, it was decided to waive the 2-hour water spray at 120°F and simply store the boxes at 120°F for 2 hours.

5. Loose-load Vibration **Vibration** ASTM D 999 - 96

Frequency of 268 cycles per minute (CPM).

1-1/2 hours with long side against the back wall, and 1-1/2 hour with short side against the back, in either order.

7. Handling **Drop Test** ASTM D 5276 - 94

21 inch height	
1 drop	top
2 drops	adjacent bottom edges
2 drops	diagonally opposite bottom corners (on joint)
1 drop	bottom

Conditions/Glossary

Any odd circumstances or variations in the test cycle were noted.

Boxes were observed throughout the test cycle and damage/changes were recorded.

After completion of the cycle, boxes were inspected and observations recorded. The boxes were inspected externally, and the contents were examined if warranted.

After all observations and measurements were obtained, a subjective Pass / Fail determination was made. A box that passed retained all contents, had good compressive strength, had no major gaps or tears (holes less than 1-inch in any dimensions considered acceptable), and could still be manually handled. Conversely, a box was deemed a failure if it had major holes or gaps, poor compressive strength, contents spilling out or exposed, or could no longer be manually handled.

The term "separation" describes a breach in a sealed area.

The term "delamination" describes the condition when the sheets of the fiberboard come apart.

The "joint" is the manufacturer's joint, which may be oriented in different locations, depending on the box design.

MRE means Meal, Ready-to-Eat.

ID is inside dimensions, in inches. OD is outside dimensions, in inches.

sl. is slight.

lb means pounds.

in. is the abbreviation for inch.

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APPENDIX D

TEST RESULTS

Test date: Feb 1998

Containers tested:

Old MRE: 1 box. V2s box (OD: 18-7/8 x 13-9/16 x 5-7/8 in.), glued joint, corrugated liner, glued top and bottom closures, V2s sleeve with glued joint. Reinforced with 2 straps. Note that the box had been in 100°F storage for 7 years.

MRE: 2 boxes. V2s box (ID: 16-1/4 x 9-1/8 x 9-7/8 in.), glued joint, glued top and bottom closures, V2s sleeve with glued joint. Box is turned 90° and sleeve covers ends and the flapped sides. Reinforced with two straps.

V3cMRE: 2 boxes. MRE design, V3c fiberboard (ID: 16-1/4 x 9-1/8 x 9-7/8 in.), glued joint, glued top and bottom closures, V3c sleeve with glued joint. Box is turned 90° and sleeve covers ends and the flapped sides. Reinforced with two straps.

Observations

	Old MRE	MRE (average)	V3c MRE (average)
Initial Weight (lb)	20.6	22.5	21.8
Heaviest weight (lb)	21.1	23.8	25.3
Handling	No Damage		
Stacking target	4100	3300	3300
MRE: 3300 lb	Sleeve creased in longitudinal direction		
Old MRE: 4100 lb			
Handling	No Damage		
Environmental	Sl. loss of squareness	Sl. separation of sleeve and joint, loss of square	Sheets on sleeve starting to separate, punk bottom
Vibration	Slight Scraping		
Handling	Corners crunched, no straps broke		

Comments

All boxes passed. Boxes appear to be over-designed.

Test date: March 1998

Containers tested:

MRE/1 strap: 2 boxes. V2s box (ID: 16-1/4 x 9-1/8 x 9-7/8 in.), glued joint, glued top and bottom closures, V2s sleeve with glued joint. Box is turned 90° and sleeve covers ends and the flapped sides. Reinforced with one strap.

V3cMRE/1 strap: 1 box. V3c box (ID: 16-1/4 x 9-1/8 x 9-7/8 in.), glued joint, top and bottom closures, V3c sleeve with glued joint. Box is turned 90° and sleeve covers ends and the flapped sides. Reinforced with one strap.

MRE/0 strap: 1 box. V2s box (ID: 16-1/4 x 9-1/8 x 9-7/8 in.), glued joint, glued top and bottom closures, V2s sleeve with glued joint. Box is turned 90° and sleeve covers ends and the flapped sides. No reinforcement with straps.

V3cMRE/0 strap: 1 box. V3c box (ID: 16-1/4 x 9-1/8 x 9-7/8 in.), glued joint, glued top and bottom closures, V3c sleeve with glued joint. Box is turned 90° and sleeve covers ends and the flapped sides. No reinforcement with straps.

Observations

	MRE / 1 strap	V3c MRE/1 strap	MRE / 0 straps	V3c MRE/0 strap
Initial weight (lb)	22.7 / 22.5	20.9 / 20.6	22.5	22.5
Heaviest weight	24.1 / 23.8	24.1 / 24.1	23.6	23.7
Handling	No Damage			
Stacking target 3300 lb	3300	3300	3300	3300
	V3c boxes appear to have more compressive strength than V2s boxes.			
Handling	No Damage			
Environmental (Note)	Soft fiberboard, joint on #2 separated	Glue held, delamination, joint on #5 separated	Joint separated, delamination	Delamination
Vibration	Slight scraping			
Handling	Out-of-round Some flaps separated	Out-of-round. Some delamination	Out-of-round Some flaps separated	Out-of-round. Some delamination

Note: Due to a malfunction, boxes were exposed to 170°F during the first 16-hour storage, the 100°F room was used until the final 16-hour exposure, when the 120°F room was used.

Comments

Though the boxes became out-of-round, some flaps separated, and there was some delamination, it was determined that the boxes marginally passed. The separated flaps were held in place by the sleeve, so that manual handling of the container was still possible. It appears that if reinforcement is deemed necessary, one girth-wise strap is adequate.

Test date: April 1998

Containers tested:

UGR H-tape: 1 box. Large V3c UGR box (ID: 23-3/4 x 13 x 8-3/4 in.), with 2 V3c full-height liner-style partitions which divide the box into 2 equal areas. Box filled with 1 full metal tray can, 1 full polymeric tray can, 1 box of stuffing, and 10 MREs. No pads. Stapled joint, Bottom and top closed by H-taping with 2" tape.

UGR C-tape: 1 box. Large V3c UGR box (ID: 23-3/4 x 13 x 8-3/4 in.), with 2 V3c full-height liner-style partitions which divide the box into 2 equal areas. Box filled with 1 full metal tray can, 1 full polymeric tray can, 1 box of stuffing, and 10 MREs. No pads. Stapled joint, Bottom and top closed with one center 2" tape.

MRE VE: 1 box. Wornick VECF box. V2s RSC box with flaps on side, with a corrugated liner. Glued closures. 2 reinforcement straps.

Observations

	UGR H-tape	UGR C-tape	MRE VE
Initial weight (lb)	34.5	35	22.7
Heaviest weight (lb)	35.8	37	23.8
Handling	No damage	Tape on 3 edges split	No damage
Stacking target	4500	4800	2400
UGR: 5700 lb			
MRE: 3300 lb			
Displacement (inches)	1 in.	1 in.	1-1/8 in.
Handling	No Damage		
Environmental	Soft fiberboard. No overt damage.		
Vibration	Slight scraping		
Handling	Metal tray leaked due to inadequate fit in box or lack of cushioning Polymeric tray O.K.	Sl. delamination Metal tray leaked due to inadequate fit in box or lack of cushioning Polymeric tray O.K.	Joint and flaps have sl. delamination and separation

Comments

Boxes passed. Damaged to metal trays due to poor packing technique. The compression strengths are lower than the formulated target, but field experience with this container indicates that the box material and design is adequate. See Appendix E for discussion on compression.

A V3c box with joints and seams sealed appears to have sufficient strength and durability. If inadvertently only center taping is applied, the container still performs adequately.

The MRE VE box performed adequately. There was a reduction in compression strength when compared to the current design (see Feb and March test reports). Issues on ease of construction, filling and closing must be addressed.

Test date: May 1998

Containers tested:

Fibreshield: 1 box. V2s MRE box with Fibreshield sleeve. Sleeve seems to be domestic grade 200 corrugated fiberboard with an inside coating. Glued joint. One reinforcing strap.

Lydall coat: 1 box. V2s MRE box with Lydall solid fiberboard sleeve, with Michelman coating on both sides. Glued joint. One reinforcing strap.

Menasha: 1 box. V2s MRE box with Menasha solid fiberboard sleeve. Glued joint. One reinforcing strap.

Lydall: 1 box. V2s MRE box with Lydall solid fiberboard sleeve. Glued joint. One reinforcing strap.

275/Lydall: 1 box. Domestic grade 275 MRE box with 11 MREs and a Lydall sleeve. Glued joint. One reinforcing strap.

Observations

	Fibreshield	Lydall coat	Menasha	Lydall	275/Lydall
Initial weight (lb)	21.74	22.75	21.84	22.34	19.77
Heaviest weight (lb)	23.4	24.0	23.6	24.0	22.1
Handling	No Damage				
Stack target 3300 lb	2500	3200	3100	3100	2700
Displace	½ in.	½ in.	¾ in.	¾ in.	1 in. bulging
Handling	No Damage				
Environment	Soft, sl. delamination coating slimy but still there	Blotchy dye, coating there, soft, water soaked on edges	Good	Good	Box soft but holding, delamination on box joint, sleeve good
Vibration	Sleeve joint separated	Sl. Scuff	Strap broke	Sl. Scuff	Box joint delaminated
Handling	Slight crushing				

Comments:

The Fibreshield box failed; the corrugated sleeve separated. Use of a corrugated sleeve with exposed flutes is highly susceptible to damage.

The other 4 boxes passed. The four sleeves constructed from solid fiberboard performed adequately. The grade 275 corrugated box, in a sleeve, passed marginally; any exposed flutes (i.e. the box joint) should be taped.

Test date: July 1998

Containers tested:

G-P RSC: 1 box. RSC box from Georgia-Pacific, constructed from USP120/33C +WRA/USP120. (ID: 15-3/4 x 8-7/8 x 10-5/8 in.) Glued joint. Center tape and H-tape with 3M Highland tape. The middle span of the joint was not sealed.

G-P Auto-Divide: 1 box. RSC box from Georgia-Pacific, constructed from USP120/33C +WRA/USP120. The one-piece box has the manufacturer's joint in the center of the box side and a center partition with a 1-1/2 inch attached flap. (ID: 19 x 8-7/8 x 10-1/8 in.) Glued joint. Center tape and H-tape with 3M Highland tape. The middle span of the joint was not sealed.

18 RSC M: 1 box. RSC box, for 18 MREs, constructed from grade 275 fiberboard. 1 center "M" partition, full height and 18 inches long with scores at 2 7, 9, 11, and 16 inches. (ID: 20-1/2 x 11-7/8 x 8-7/8 in.) Glued joint. Center tape and H-tape with 3M Highland tape. Note that the box was bulging slightly and the flaps did not meet. The middle span of the joint was not sealed.

18 RSC Z: 1 box. RSC box, for 18 MREs, constructed from grade 275 fiberboard. 1 center "Z" partition, full height and 16 inches long with scores at 2 and 14 inches. (ID: 20-1/2 x 11-7/8 x 8-7/8 in.) Glued joint. Center tape and H-tape with 3M Highland tape. Note that the box was bulging slightly and the flaps did not meet. The middle span of the joint was not sealed.

Observations

	G-P RSC	G-P Auto-Divide	18 RSC M	18 RSC Z
Initial weight	20.0	20.8	31.4	30.4
Heaviest weight	22.1	22.3	34.7	30.7
Handling	No Damage			
Stack Target:	650	1550	1650	1100
G-P: 2700 lb				
18: 4000 lb				
Displacement	1/2 in.	3/4 in.	1 in.	3/4 in.
Handling	No Damage			
Environment	Sl. gash in upper edge, exposed area of joint separated and delaminated	Exposed center joint separated and delaminated	Exposed area of joint separated and delaminated	Exposed area of joint separated and delaminated
Vibration	Slight scuffing			
Handling	Bottom center seam and half of one H-taped seam broke	Bottom center seam and half of each H-taped seam broke	Bottom center seam and one H-taped seam broke	Soft corners, no seams broke

Comments: All these boxes failed. The grade of the fiberboard and lack of adequate inner support led to boxes that did not meet the compression goals. The exposed area of the manufacturers joint, the gaping at the closures due to overstuffed containers, and the grade of the fiberboard led to some seam failures during the final handling cycle of drops.

APPENDIX E

DISCUSSION ON COMPRESSION

The compressive strength required for a box to achieve safety and maintain integrity of the goods is based on the knowledge of the contents, the inherent strength of the materials used in the construction of the box, the design of the box, and the expected rigors the box will experience during the distribution cycle.

Three different methods to determine the compressive target loads of the box were considered. All three methods calculated compressive strengths within 10% of each other. Compressive target loads for the 1997 MRE box are calculated at encl 1.

The ASTM D 4169 method uses the individual filled box weight, the box height, the height of the stack of unit loads, and a safety factor. (encl 2)

The method cited in the Fibre Box Association (FBA) report "Corrugated Board Edge Crush Test (ECT) Application and Reference Guide" involves the weight of a layer of boxes, the number of layers in the stack and the factor elements for stack configuration, humidity and storage time (a more severe factor of .25 for the storage was used, to account for the 3-year storage requirement for rations). (encl 3)

The third method uses actual known measurements of weights and stack heights to determine the compressive load felt by each box on the first layer, then multiplied by a safety factor.

A safety factor of 8 was chosen for boxes subjected to the ASTM D 4169, Cycle 18, Assurance Level I. This was based on the overall decision to use Assurance Level I for all the ASTM D 4169 tests. If the individual boxes were unable to attain the target compressive load, the maximum compressive load reached and the displacement were recorded, any damage was noted, and the test cycle was continued.

The article "Estimating the Effects of Interiors on Corrugated Box Stacking Strength" by Surber and Catlin (encl 4) is a thorough discussion on compressive strength.

Based on the information cited and the results of the in-house ASTM D 4169 testing, it is recommended that military food ration boxes be designed to a compressive strength safety factor of at least 6 if there is overhang on the unit load and at least 5 if there is no overhang.

Compression Load Calculations

1. ASTM D 4169:

$$L = M \times (J \times H - h/h) \times F = 24 \text{ lb} \times (1 \text{ lbf/lb} \times 171 \text{ in} - 9.25 \text{ in} / 9.25 \text{ in}) \times 8 = 3250 \text{ lb}$$

2. FBA:

$$\text{Load on bottom layer} = 288 \text{ lb per layer} \times 15 \text{ layers} + 180 \text{ lb (pallets)} = 4500 \text{ lb}$$

$$\text{Load per box} = 4500 \text{ lb} / 12 \text{ boxes/layer} = 375 \text{ lb}$$

$$\text{Required compressive strength} = 375 \text{ lb} / .85 \times .61 \times .25 = 2885 \text{ lb}$$

3. Actual measurements multiplied by safety factor:

$$\text{Weight of boxes/unit load} \times 4 \text{ pallets high} + 180 \text{ lb (pallets)} - 288 \text{ lb (boxes per layer)} \div \text{boxes per layer} \times \text{safety factor}$$

$$1250 \times 4 + 180 \text{ lb} - 288 \text{ lb} \div 12 \times 8 = 3260 \text{ lb}$$

Recommendation:

The three methods calculated values of:

3250 lb

2885 lb

3260 lb

Mathematical average is 3130 lb

Recommend that these boxes be subjected to a compressive load of 3150 lb for in-house ASTM D 4169 testing, Assurance Level I (safety factor of 8).

ASTM D 4169: Practice for Performance Testing of Shipping Containers and Systems

(b) *Unitized Loads, Large Shipping Cases, and Crates—Grabhook/Sling Handling*—Using the procedures specified in Test Methods D 1083 – 91, pick up and set down to determine load instability, deformation, or damage caused by the lifting means. This test is only applicable for Assurance Level I, with one cycle being performed for each possible lifting orientation.

(c) *Large Shipping Cases and Crates—Tip/Tipover*—Using the procedures of Test Methods D 1083, test containers tip and their resistance to accidental tipover and impact. Assurance Level I will require one tipover on each of two opposite sides, as determined by that initial side having the lowest height-to-width ratio. This test is not applicable for Assurance Levels II and III.

11.4 Element C—Warehouse Stacking:

11.4.1 The test levels and the test method for this element of a distribution cycle are intended to determine the ability of the shipping unit to withstand the compressive loads that occur during warehouse storage. The required loading must consider the effects of length of time in storage; the alignment or stacking pattern of the container; variability in container strength, moisture content, temperature, previous handling, and transportation; and method of load support. The required loads for typical shipping units which include the combined effects of the preceding factors are recommended as follows:

Test Method—D 642.

Conditioning—73.4 ± 2°F (23 ± 1°C), 50 ± 2 % relative humidity in accordance with Practice D 4332.

11.4.2 Use the following test levels:

Shipping Unit Construction	F-Factors Assurance Level		
	I	II	III
1. Corrugated, fiberboard, or plastic container that may or may not have stress-bearing interior packaging using these materials, and where the product does not support any of the load	8.0	4.5	3.0
2. Corrugated, fiberboard, or plastic container that has stress-bearing interior packaging with rigid inserts such as wood	4.5	3.0	2.0
3. Containers constructed of materials other than corrugated, fiberboard, or plastic that are not temperature or humidity sensitive or where the product supports the load directly, for example, compression package.	3.0	2.0	1.5
4. If the product supports a known portion of the load, the <i>F</i> -factor is calculated in the following manner:			

$$F = P(F_p) + C(F_c)$$

where:

F_p = factor given above for compression package (Construction Type 3).

P = percent of load supported by product,

F_c = factor given above for appropriate container construction, and

C = percent of load supported by container.

If a full pallet load is tested, *F* factors may be reduced by 30 %.

11.4.3 Load the shipping unit to the computed load value, as follows. Remove the load immediately after reaching the specified value.

$$L = M \times J \frac{H - h}{h} \times F$$

where:

L = computed load, lbf or N,

M = mass of one shipping unit or individual container, lb or kg.

J = 1 lbf/lb 9.8 m/s².

H = maximum height of stack in storage, in. m,

h = height of shipping unit or individual container, in. m and

F = factor to account for the combined effect of the individual factors described above.

11.5 Element D—Vehicle Stacking:

11.5.1 The test levels and test methods for this element of the distribution cycle are intended to determine the ability of the shipping unit to withstand the compressive loads that occur during transport in carrier vehicles. The required loading must consider the effects of time and vibration in transport, the alignment or stacking pattern of the container, variability in container strength, moisture content, temperature, previous handling, and method of load support. The required loads for typical shipping units which include the combined effects of the above factors are recommended below. Element D should only be used in conjunction with Element F Loose Load Vibration or Element G Vehicle Vibration in a performance test. Since Element E Stacked Vibration combines the effect of vibration and compression, it is not required to conduct Element D Compression in conjunction with Element E.

Test Method—D 642.

Conditioning—73.4 ± 2°F (23 ± 1°C), 50 ± 2 % relative humidity in accordance with Practice D 4332.

11.5.2 Use the following test levels:

Shipping Unit Construction	F-Factors Assurance Level		
	I	II	III
1. Corrugated, fiberboard, or plastic container that may or may not have stress-bearing interior packaging using these materials, and where the product does not support any of the load	10.0	7.0	5.0
2. Corrugated, fiberboard, or plastic container that has stress-bearing interior packaging with rigid inserts such as wood	6.0	4.5	3.0
3. Containers constructed of materials other than corrugated, fiberboard, or plastic that are not temperature or humidity sensitive or when the product supports the load directly, for example, compression package	4.0	3.0	2.0
4. If the product supports a known portion of the load, the <i>F</i> factor is calculated in the following manner:			

$$F = P(F_p) + C(F_c)$$

where:

F_p = factor given above for compression package (construction type 3).

P = percent of load supported by product,

F_c = factor given above for appropriate container construction, and

C = percent of load supported by container.

If a full pallet load is tested, *F* factors may be reduced by 30 %.

11.5.3 For vehicle stacking made up of identical shipping units, load the shipping unit to the computed load value, as calculated below. Remove the load immediately after reaching the specified value.

$$L = M \times J \frac{H - h}{h} \times F$$

where:

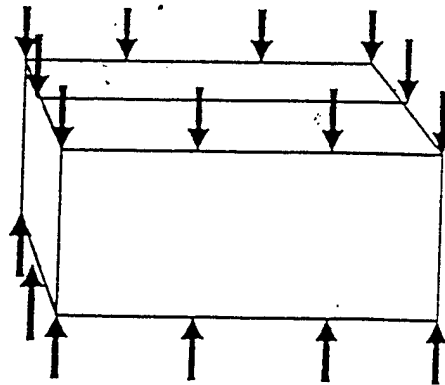
L = computed load, lbf or N,

M = mass of one shipping unit or individual container, lb or kg.

J = 1 lbf/lb or 9.8 m/s²,

Fibre Box Association Application and Reference Guide . 1992
Corrugated Board Edge Crush Test (ECT)

BOX COMPRESSION STRENGTH



Box compression (top-to-bottom) or stacking strength is an important performance characteristic when the boxes will be expected to maintain their structure under load. Customers' requirements for box compression strength are a function of the weight of the boxed contents, the number of layers in the stack, the type of unitizing, the number of units high the package is stacked in the warehouse, warehouse environment, time under load, and transportation and other distribution conditions.

To evaluate the impact of the unit load and distribution conditions, etc., a "factor" should be developed. This "factor" is a number that is derived from the relationship between box compression strength at standard conditions, as compared to load and transportation and storage conditions that will be applied to the box in its expected distribution environment.

The appropriate "factor" for the distribution conditions should be considered before any box is specified by top-to-bottom compression (or ECT). Methods for developing a "factor" are discussed in ASTM D 4169 (see Standard Test Methods and Practices, General Performance Evaluation page 25, "factor" discussion is in sections 8 through 11 of D 4169) and chapters 8, 9 and 10 of Corrugated Shipping Containers, by George Maltenfort (see References page 28), and often in computer aided stacking strength and pallet pattern optimization software programs. The previous distribution history of the package can be very useful for determining the increment of protection needed, if it is available.

Example: Calculating the Required Compression

For gross weight per box of 25 pounds, 10 boxes per layer, 5 layers per unit, warehouse stacking 2 units high:

Weight per layer is 250 pounds

Number of Layers Stacked is 10

Pallet weight 75 pounds

Load on Bottom Layer is:

$$250 \text{ pounds} \times 9 \text{ (layers above bottom box)} + 75 \text{ pounds} = 2325 \text{ pounds}$$

Load per Bottom Layer Box is:

$$\frac{2325 \text{ pounds}}{10 \text{ boxes per layer}} = 232.5 \text{ pounds}$$

An example of methods used to determine the "factor":

VARIABLES	INPUT	FACTOR ELEMENTS *
Stacking Pattern	Column Stack	.85
Max. Rel. Humidity	85% R. H.	.61
Storage Time	270 Days	.50

Example: Continued

Considering the effects of stacking pattern, humidity and storage time, and the required warehouse stacking strength per box, the required top-to-bottom compression strength would need to be:

$$\begin{aligned} \text{Required Compression Strength} &= \frac{232.5 \text{ pounds}}{.85 \times .61 \times .50} \\ &= \frac{232.5 \text{ pounds}}{.259} \\ &= 900 \text{ pounds (when rounded)} \end{aligned}$$

- * These numbers have been chosen as an example. The appropriate "factor" for individual situations should be determined carefully, according to the distribution environment of the boxes being ordered.

Estimating the effects of interiors on corrugated box stacking strength

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Introduction. The corrugated box is probably the best all-around packaging available, but it doesn't work by chance—it works by design. The more you know about the performance characteristics of corrugated boxes, the better the box will work for you.

Stacking is one of the corrugated box's most important functions. There are many factors to consider when designing a box so that it will stack adequately. These include size and grade of the box, weight of the product in each box, number of tiers per pallet, number of pallets in each stack, humidity exposure, duration of stacking, handling methods used, stacking patterns and value of the product.

Safety factor. There are a number of different places to begin your design planning but the best one is with a consideration of the safety factor. This is the degree of safety that you have in a real-life stacking situation. In order to determine the safety factor for a given situation, you must determine the strength of the box being used, and the total weight resting on top of the box in an actual stack. Total weight is a function of the weight of each filled box, the number of boxes per tier, the number of tiers per pallet and the number of pallets in the stack. From this information, you can determine the actual weight on each box on the bottom tier of the load. Safety factor, then, is individual box strength divided by the actual weight on each bottom box.

$$\text{Safety factor} = \frac{\text{Individual box strength}}{\text{Actual weight on each bottom box}}$$

Since you cannot calculate safety factor without knowing box strength, consider the safety factor needed and calculate the required box strength from that. The formula is:

$$\text{Required individual box strength} = \text{Actual weight on each bottom box} \times \text{safety factor}$$

One "rule of thumb" states that you need a safety factor of five. This means that you can stack a load equal to only 20 percent of the box strength on any given box. Some products are stacked with a safety factor of less than five and others require a safety

Summary: The purpose of this article is to help narrow the number of options that need to be considered when designing a corrugated package. The authors have measured the effects of some of the more common corrugated interiors on box compression strength and offer the results of this work in 32 different configurations.

Once options have been narrowed, laboratory testing will assure that the estimates hold for a specific package/product combination. However, it may be necessary to conduct field tests as well.

The important performance characteristics discussed should enable readers to meet their expectations at a more optimum cost/strength relationship.

factor greater than five. The required safety factor depends on the length of stacking time, humidity exposure, pallet size, stacking pattern, the care taken in stacking, the value of the product and other considerations.

The box size, normally established by product size, enables us to estimate the stacking strength by measuring its compression strength. Compression is the strength of a box measured in a laboratory under dynamic (moving) load at standard conditions (73°F. and 50 percent R. H.). This gives us the potential strength of the box. But, compression strength is not stacking strength. Stacking strength is the load that a box can take in the warehouse just before the stack falls over. True stacking strength is something that we really can't afford to measure, so we estimate it by measuring compression strength.

Table I shows an estimate of what a 200-pound test, C-flute RSC with 26-pound medium will test in the laboratory at various perimeters. A 200-pound test, B-flute RSC of the same perimeter will test only 90 percent as high (multiply the C-flute value by 0.9), and a 200-pound A-flute RSC will be about ten percent greater than C-flute (multiply C-flute value by 1.1).

Note that Table I gives an estimated compression. The word "estimated" means that, over the years,

Table I
Estimated compression strength of a 200-pound test, C-flute RSC with 26-pound medium at various perimeters

Perimeter in inches	Compression in pounds
30	507
35	550
40	595
45	637
50	680
55	718
60	755
65	793
70	822
75	852
80	877
85	900
90	919
95	931
100	943

Table II
Compression strengths of C-flute boxes made from other grades of corrugated board compared with those manufactured from 200-pound test C-flute

Grade of board	Multiplying factor
125	0.65
150	0.84
175	0.92
200	1.00
200 (33 medium)	1.10
200 (40 medium)	1.18
275	1.40
350	1.60
200 DW	1.50
275 DW	1.85

we have found that 200-pound test, C-flute boxes of good quality will average out at these values. There is a run-to-run variation within good-quality boxes that results in a range of \pm eight to ten percent around these averages. Thus, these numbers are not absolute, nor are they minimums. They work well for estimating the success of a box in a stacking situation, but they are not quality standards.

Table II shows the relationships for the compression strengths of C-flute boxes made from other grades of corrugated board by providing a multiplying factor. Although we can change board grade and obtain compression strength increases, there is a maximum limit. If the box compression strength does not result in a high enough safety factor at a low enough cost, you have several choices: reduce the size of the stack, go from an interlock stacking pattern to a column stacking pattern, or put corrugated interiors in the box.

Commonly used interiors. There are as many dif-

ferent interior styles as there are individual box designers but some forms are more common than others. Their functions are primarily to separate product and to increase stacking strength. The factors to consider when selecting interiors include ease of set up, ease of loading product into the box, product protection (from scuffing, etc.), stacking strength and cost. The effects of some of the more common corrugated interiors on box compression strength are provided in Figure 1.

This work was conducted with a 19 $\frac{1}{2}$ " x 12 $\frac{1}{2}$ " x 12 $\frac{1}{2}$ " 200-pound test, C-flute RSC. The object was to determine the increase in compression strength for various 200-pound test, C-flute interior forms. The primary number in Figure 1 is that called "percent strength increase with interior."

For example, we see from Table I that a 200-pound test C-flute box with a perimeter of 75 inches (22 $\frac{1}{2}$ " x 15" x 12 $\frac{1}{2}$ ") would average 852 pounds of compression in the laboratory. If we put interior style No. 19 into the box, this interior would theoretically add 818 pounds of compression (multiply box value of 852 x 0.96 factor from Figure-1). This results in a combined compression of 1,670 pounds (852 + 818).

Now that we have established a relationship between the box and the corrugated interiors, we can estimate the effect of changing board grade in either the box or the interior by using Table II.

Assuming that we have already determined that the actual load on the bottom box will be 475 pounds and that we want a safety factor of four or more, we determined that a 200-pound test RSC with a 200-pound test style No. 19 interior will have a compression strength of 1,670 pounds.

Dividing the total package strength (1,670) by the actual load (475) results in a safety factor of 3.52. Assuming that we want to use the style No. 19 because it handles well in our system, we must increase either the grade of the box or the grade of the interior to meet our safety factor of four. If we increase the grade of the box to 275-pound test:

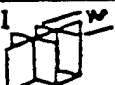
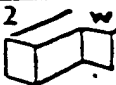






$$\begin{array}{rcl}
 275\text{-pound box } (852 \times 1.4) & = & 1,193 \\
 200\text{-pound interior} & = & 818 \\
 \text{Total package} & = & 2,011 \\
 \text{Safety factor} = \frac{2,011}{475} & = & 4.23
 \end{array}$$


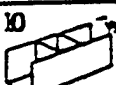

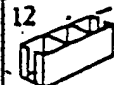



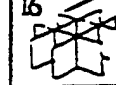
Thus, increasing the grade of the box would provide the desired safety factor.









If we increase the grade of the partition to 275-pound test and leave the box at 200-pound test, this happens:

$$\begin{array}{rcl}
 200\text{-pound box} & = & 852 \\
 275\text{-pound interior } (818 \times 1.4) & = & 1,145 \\
 \text{Total package} & = & 1,997
 \end{array}$$

$$\text{Safety factor} = \frac{1,997}{475} = 4.20$$

STYLE								
Package Compression	955	961	971	989	1100	1146	1198	1205
% Strength Increase With Interior	25	26	27	29	44	50	57	58
% Cost Increase With Interior	81	46	147	51	61	132	93	91
Square Ft. of Interior	4.2	2.71	1.74	3.1	3.3	1.21	5.5	5.6

STYLE								
Package Compression	1223	1233	1246	1297	1375	1394	1438	1446
% Strength Increase With Interior	60	61	63	70	80	82	88	89
% Cost Increase With Interior	69	169	46	173	66	90	128	93
Square Ft. of Interior	3.8	10.8	2.72	10.8	3.8	5.6	7.7	5.4

STYLE								
Package Compression	1453	1488	1604	1537	1593	1604	1627	1661
% Strength Increase With Interior	90	95	96	101	108	110	113	117
% Cost Increase With Interior	96	73	91	126	114	91	72	73
Square Ft. of Interior	5.4	4.3	5.4	7.6	6.5	5.4	4.0	4.3

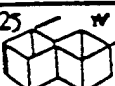







STYLE								
Package Compression	1715	1735	1749	1783	1891	1924	2718	764
% Strength Increase With Interior	124	127	129	133	148	152	256	—
% Cost Increase With Interior	89	100	97	93	144	126	158	0
Square Ft. of Interior	5.4	6.1	5.4	5.5	8.7	7.5	9.6	11.75

Figure 1
A guide (only) for obtaining the safety factor based upon a rectangular box of a given size and shape.

Either approach will enable us to obtain the desired safety factor. We can calculate that the interior approach uses less board (6.31 square feet) per package than the box approach (14.86 square feet). Therefore, we would increase the grade of the interior to 275-pound test and keep the box at 200-pound test to obtain the most effective package.

The effects on compression shown in Figure 1 are to be used as guides, not as iron-clad projections of minimum package compression strength. They will give you a quick idea of how far you may need to go to obtain the safety factor required. Also, the data presented is for a rectangular box of a given size and shape. Other shapes will result in some differences.

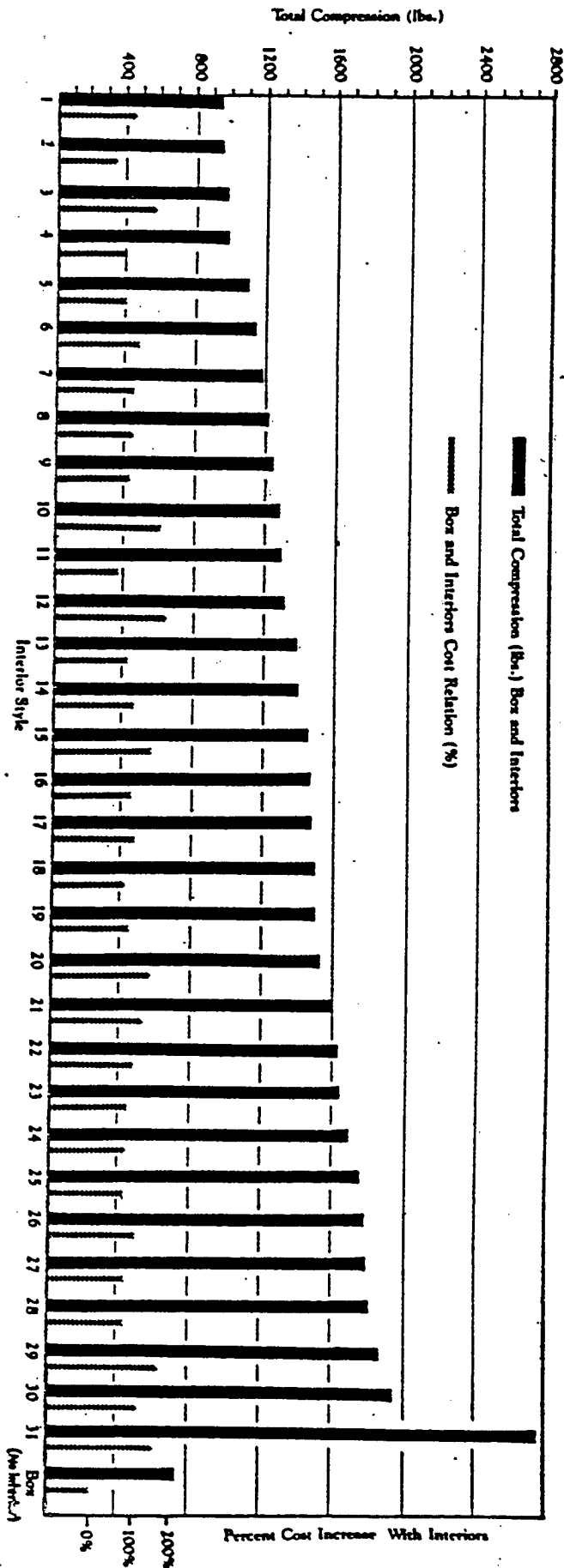


Figure 2
Total package compression for each style studied to show the box interior relationship.

Further analysis of the data in Figure 1 indicates that:

1. If we add the lineal inches of the perimeter of the box to the lineal inches of the interior and plot this versus package compression, we find a relatively good linear relationship.
2. The number of 90° angles in the interior plotted against package compression also results in a relatively good linear relationship.

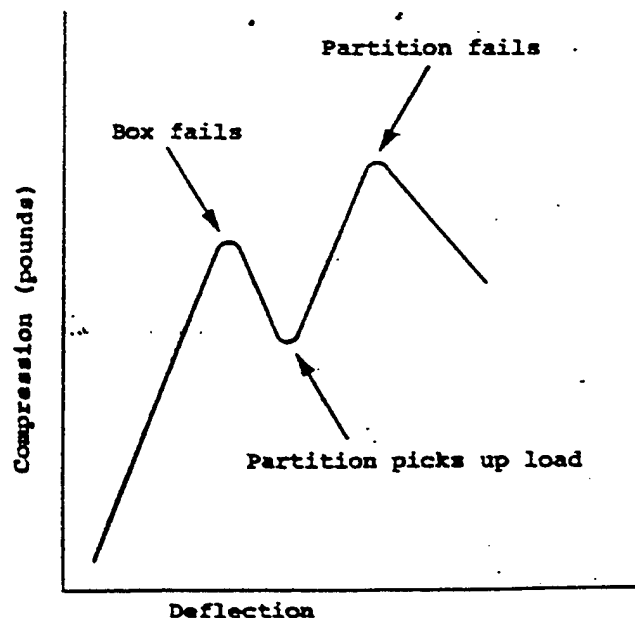
Figure 2 shows the total package compression for each style studied as well as the cost relationship of each box and partition as a percentage of the cost for the box alone.

For example, this figure shows that styles No. 2 and No. 11 add very different strengths to the RSC but add very little difference in cost. The optimum choice from a strength and cost standpoint would be style No. 11. There may be other factors which dictate style No. 2. One such factor would be that you can't divide six bottles with style No. 11 but, you can with style No. 2.

Another important consideration is how well the box and the interior work together. The critical factor here is the depth relationship between the two. If the partition is too short, the box will take all of the load until a certain deflection (fatigue) has been reached, and then the interior will pick up the load. When the two have a proper depth relationship, a higher compression and a lower deflection is achieved. Figures 3 and 4 show how this appears on laboratory stress-strain curves.

We recommend that the interior depth be specified $\frac{1}{16}$ " greater than the inside depth of the

Figure 3
Laboratory stress/strain curve shows box failing at top of first peak. Partition picks up load in valley and fails at top of second peak.



box. We will specify a $\frac{1}{8}$ " difference in those cases where there is enough sealing compression to avoid rounding of the top or bottoms of the sealed boxes.

Other factors to consider in interior selection. How difficult an interior is to set up and position in the box is an important factor, in addition to the compression strength that it offers. You must consider whether this is a manual or an automatic operation and whether flap support is necessary. If the contents (bottles for example) are unloaded automatically, will the interior maintain its position for reloading? Many products add to the load bearing capability of the box. This support value can be determined in laboratory testing.

Conclusion. This article should help you to narrow the number of options that need to be considered in designing a corrugated package with an interior when stacking strength is a major consideration.

Once options have been narrowed, laboratory testing will assure you that the estimates hold for a specific package/product combination. However, it may be necessary to conduct field tests as well. Attention to the important performance characteristics discussed in this article should enable readers to meet their expectations at a more optimum cost/strength relationship.

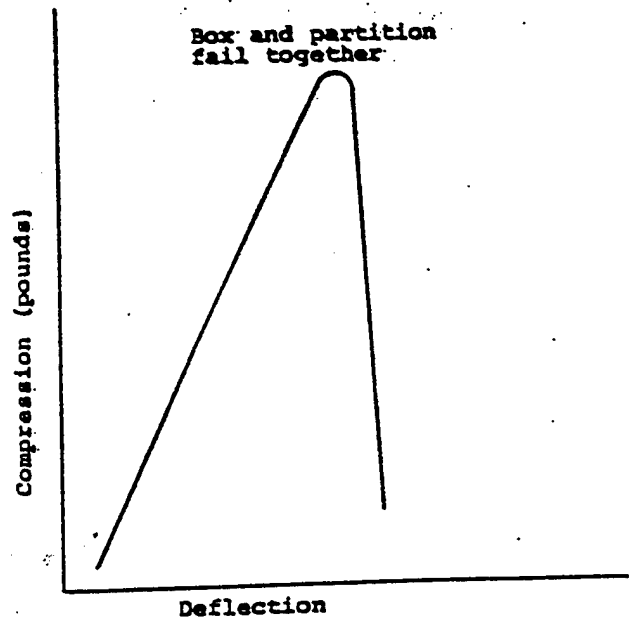


Figure 4
Laboratory stress/strain curve showing box and partition failing together.

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technology

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APPENDIX F

DISCUSSION ON REPULPABILITY OF FIBERBOARD

The recycling of fiberboard is a common process. It is accomplished by repulping the fiberboard and then using it in the manufacture of paper products.

When fiberboard is treated with speciality substances to enhance some aspect of its performance (i.e, flame resistance, water resistance, durability), the ability of the fiberboard to repulp may be degraded. V2s solid fiberboard and V3c corrugated fiberboard are manufactured with water-resistant resin in the linerboard and with water-resistant adhesive in between the sheets of the finished board.

Repulpability tests performed on V2s and V3c fiberboard by three prominent companies in the paper industry (Georgia-Pacific, Weyerhaeuser, and Stone Container) are enclosed. Considering the variety of methods and the qualitative nature of these tests, it is obvious that these water-resistant boards do not repulp as well as domestic board.

V2s is so highly resistant to repulping that paper mills typically refuse this material. There is a very low level of repulped material and a high level of contaminates and rejected material that must be discarded. In essence, V2s is not recyclable.

V3c, due to its corrugated construction, will produce a higher level of repulped material than V2s. Paper mills will accept V3c, especially if it is mixed with other paper/fiberboard. In essence, V3c is recyclable.

It is recommended that government and military packing use domestic grade fiberboard whenever it is feasible. But it is acknowledged that, due to the extreme conditions that may be encountered distribution and storage, the use of weather-resistant fiberboard may be required. It is then highly recommended that corrugated weather-resistant fiberboard (V3c, W5c and the other grades cited in ASTM D 4727) be used.



Georgia-Pacific
Containerboard and Packaging Division
Materials Test Lab
Cedar Springs, GA 31732

Technical Services Inquiry

Inquiry Number: TSI 98-023

Date: February 4, 1998

Submitted By: Jim F. Perry

Customer/Source of Inquiry: **Company:** Georgia-Pacific
Address: Technology & Development Center
Norcross, GA

Priority: ☐ Urgent
☒ Routine

Inquiry Description: Repulpability determination on two samples submitted by Carol Norton U.S. Army Natick R & D.

Inquiry Conclusion: Samples are agitated with 2 liters of water in a British pulp disintegrator. The sample is visually inspected after 500 counts (12,500 rev.) initially and after each successive 250 counts. 500 counts usually would be enough agitation to disintegrate regular grade linerboard. Sample V2 after 7000 counts contained large fiber bundles evident in the slurry and in the handsheet. The V3c sample disintegrated quicker but at 4000 counts it also had small fiber bundles evident. Handsheets from each sample will be forwarded to you.

V2s	V3c
Gaylord Bogalusa, LA 350 psig laminated solid fiber	singlewall corrugated
7000 counts	4000 counts

Date Received: 01/30/98
Date Responded: 02/04/98
Response By: J. Scarborough

Distribution: B. Dew
B. A. Garner
J. F. Perry
J. R. Retzke
File



8 Woodlawn Green, Suite 209
Charlotte, North Carolina 28217
Tel (704) 521 6450
Fax (704) 521 6456

November 20, 1997

Mr. Maxwell Meyers
U.S. Army Natick Research
Development and Engineering Center
Ration Systems Division
Natick, MA 01760-5018

Recycling

Marcia F. Smith Florida Accounts Manager

NEW ADDRESS: P.O. Box 270423
Tampa, FL 33688-0423
(813) 908-5117 FAX: (813) 908-5780
Voice Mail: 1-800-338-1542, Box 1879



Dear Maxwell:

Thank you for sending your V2 and V3 samples out to Brian Mulderich in our technology center in Washington. Sorry it has taken so long to get the results to you, and thank you for your patience.

Our repulpability tests recreate paper manufacturing in the laboratory. We use the same chemicals, same screens, and a miniature version of one of our huge paper machines to test how well your samples could be repulped and made into new board.

We tested your samples with an average PH (7.4) and also a high acid PH (9.3) to simulate the ranges available in "real life". If you look at the attached chart, we included the typical Weyerpak Liner rates for you for comparison of the rates. An acceptable repulpability rate for most mills is in the 70-85% range, with 80-85% being ideal. This means that 80-85% of the fiber presented for recycling (typically baled material from your various sites, for example) is suitable and has been remanufactured.

This is determined by looking at the rejects that are left AFTER the manufacturing process is complete. Again, ideally 15-30% or less of the fiber will be non-repulpable, with the goal being 15-20% or better. Your rejects in both samples were quite high, as you suspected, mainly due to wet strength, an ingredient added to your liner to make it stronger, water-resistant and basically give it all the properties you need for the field conditions you described.

The good news is that you already have taken steps to improve the recyclability of your ration boxes—V3 is an improvement over the more rigid V2. If you are committed to increasing the repulpability of your end product, your current vendor (Gaylord, I think) may offer some suggestions.

Or if you are able to look at different vendors, I can get you in touch with some of our people in our Weyerhaeuser Containerboard/packaging division who handle large national box contracts and also our department of Technical Development in Aurora IL. They work closely with other customers in the selection and development of the right containers to match your specific criteria.

Repulpability Test Results
Weyhauser
November 1997

					Page 1		
		V2 SOLID FIBERBOARD / V3 CORRUGATED FIBERBOARD					
		REPULPABILITY STUDY					
					%6 CUT	%6 CUT	
			SAMPLE	PH	ACCEPTS	REJECTS	
			V2	7.4	53.6	46.4	
			V2	9.3	56.1	43.9	
			V3	7.4	48.3	51.7	
			V3	9.3	59.2	40.8	
			Weyerpak	7.2	70-85%	15-30%	
			liner				

JL Wilson
6/8/98

STONE CONTAINER
ATLANTA TECHNICAL LAB
MTC

5-Jun-98
1933MTC
Tested by Patricia Stewart

TEST	SAMPLE NO.		NO. OF
	V23 SOLID FIBER	V30 CORRUGATED	TESTS
REPULPABLE*	25%	80%	2
RECYCLABLE	YES	YES	2
CONTAMINATES**	NO	NO	1

*after 10 mins. in a blender

**no contaminates which could not be handled by a mill's recycling operation under normal procedure.